

The Ultraviolet Spectra of the Weak Emission Line Central Stars of Planetary Nebulae

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ABSTRACT

The ultraviolet spectra of all “weak emission line central stars of planetary nebulae” (WELS) with available *IUE* data are presented and discussed. We performed line identifications, equivalent width and flux measurements for several features in their spectra. We found that the WELS can be divided in three different groups regarding their UV: i) Strong P-Cygni profiles (mainly in C IV $\lambda 1549$); ii) Weak P-Cygni features and iii) Absence of P-Cygni profiles. The last group encompasses stars with a featureless UV spectrum or with intense emission lines and a weak continuum, which are most likely of nebular origin. We have measured wind terminal velocities for all objects presenting P-Cygni profiles in N V $\lambda 1238$ and/or C IV $\lambda 1549$. The results obtained were compared to the UV

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data of the two prototype stars of the [WC]-PG 1159 class, namely, A30 and A78. For WELS presenting P-Cygni, most of the terminal velocities fall in the range $\sim 1000 - 1500 \text{ km s}^{-1}$, while [WC]-PG 1159 stars possess much higher values, of $\sim 3000 \text{ km s}^{-1}$. The [WC]-PG1159 stars are characterized by intense, simultaneous P-Cygni emissions in the $\sim 1150 - 2000\text{\AA}$ interval of N V $\lambda 1238$, O V $\lambda 1371$ and C IV $\lambda 1549$. In contrast, we found that O V $\lambda 1371$ is very weak or absent in the WELS spectra. On the basis of the ultraviolet spectra alone, our findings indicate that [WC]-PG 1159 stars are distinct from the WELS, contrary to previous claims in the literature.

Subject headings: planetary nebulae:general - stars:fundamental parameters - stars:atmospheres - ultraviolet:stars

1. INTRODUCTION

Central stars of planetary nebulae (CSPN) that are hydrogen deficient are generally divided in three main groups: [WR], PG 1159 and [WC]-PG 1159 stars. The first one present spectra with strong and broad emission lines mainly from He, C and O, similar to the Wolf-Rayet stars (WR) of Population I. Depending on the ionization stages of the elements dominating the atmosphere, [WR] stars are subdivided in [WCL], [WCE] and [WO] (Crowther et al. 1998; Acker & Neiner 2003). On the other hand, PG 1159 stars are quite distinct objects. They are pre-white dwarfs and show mainly absorption lines of He II and C IV in their spectra (Werner et al. 1997). Only a handful of PG 1159 stars are known to possess wind features (Koesterke et al. 1998; Koesterke & Werner 1998). The [WC]-PG 1159 group present strong P-Cygni lines in the ultraviolet (e.g. N V $\lambda 1238$ and C IV $\lambda 1549$) and resemble the PG 1159 stars in the optical. Three objects are considered prototypes of this class: A 30, A 78 and Longmore 4 (at outburst).

The origin and evolution of hydrogen deficient CSPN have been investigated from different point of views during the last decade. Evolutionary models are now able to provide a reasonable match to the observed chemical abundances, although it is still debated the role of binarity and different thermal pulse models (De Marco & Soker 2002; Herwig 2001). Nebular analyses as well as sophisticated non LTE atmosphere models have been also very useful to address several questions regarding these central stars: it is generally inferred that the groups above mentioned form the following evolutionary sequence: late type [WR] \rightarrow early-type [WR] \rightarrow [WC]-PG 1159 \rightarrow PG 1159 \rightarrow non DA white dwarfs (see e.g. Zijlstra et al. 1994; Peña et al. 2001; Koesterke 2001). However, this scenario has important issues unsolved, such as the C/He mass ratio and the exact position of [WC]-PG 1159 stars in the

HR diagram (Hamann 1997; Marcolino et al. 2007). Moreover, the evolutionary status of the so-called “weak emission line stars” and their relation to the [WC]-PG 1159 stars is not at all clear. Let us discuss it now.

In an extensive observational study, Tylenda et al. (1993) analyzed spectroscopy data of 77 hydrogen deficient CSPN. In their sample, 39 were classified as [WR] stars. The remaining objects were called “weak emission line stars” (WELS or [WELS]). According to these authors, the WELS show emission of C IV $\lambda 5805$ (actually C IV $\lambda\lambda 5801, 12$) systematically weaker and narrower than in [WR] stars, and a feature in $\lambda 4650$, which is possibly a blend of N III, C III and C IV emissions. Moreover, C III $\lambda 5696$ is very weak or absent. These optical characteristics were confirmed by Marcolino & de Araújo (2003) with a homogeneous and higher resolution set of data. Interestingly, by comparing a large sample of WELS, [WC]-PG 1159 and PG 1159 spectra, Parthasarathy et al. (1998) claimed that the WELS and the [WC]-PG 1159 stars actually constitute the same class. However, this claim was based solely on comparisons of optical spectra and was not confirmed by further studies. Indeed, some authors argued that this assertion should be taken with caution until an analysis of a larger sample of objects is performed (e.g. Werner & Herwig 2006).

Undoubtedly, the “weak emission line stars” (WELS) constitute the least understood class of hydrogen deficient CSPN. An important point is that the WELS might not be descendants of the [WR] stars, as it is explicated in the [WR] \rightarrow [WC]-PG 1159 (=WELS) \rightarrow PG 1159 evolution. Penã et al. (2003) for example, derived lower average nebular expansion velocities for WELS than for [WR] stars, while the contrary would be expected from the long-term action of a stellar wind on a planetary nebula during a [WR] \rightarrow WELS transition. Furthermore, based on a kinematical study of a large sample of planetary nebulae, Gesicki et al. (2006) raised the interesting possibility that some WELS can be progenitors of the hottest [WR] stars, i.e., the [WO] group (WELS \rightarrow [WO]). A major issue hinders the determination of the evolutionary status of the WELS: their physical parameters (e.g. T_{eff} , v_∞ and \dot{M}) and chemical abundances remain unknown. The properties of A 30, A 78, and Longmore 4 ([WC]-PG 1159 stars) are known (Koesterke 2001) but again, their identity as WELS is questionable.

So far, most of previous studies involving WELS were done in the optical part of the spectrum. In fact, the very definition of a WELS is based in the optical features in $\lambda 4650$, C IV $\lambda 5805$ and C III $\lambda 5696$ (Tylenda et al. 1993). A few works in the ultraviolet including some WELS can be found in the literature. However, they often include stars of different spectral classes (e.g. Feibelman 2000), and/or are focused in the determination of nebular properties (e.g. Adams & Seaton 1982; Pottasch et al. 2005), without special attention to the WELS and their evolutionary state. Motivated by this fact and considering the open

questions above described, we investigate in this paper the UV spectra of all WELS with available *IUE* (*International Ultraviolet Explorer*) data. Our main aims are to understand their main UV characteristics; identify and measure the most intense spectral lines; measure wind terminal velocities from the available P-Cygni profiles; and finally, to compare the results to the data of the two prototype [WC]-PG 1159 stars: A30 and A78.

The present paper is organized as follows: in Section 2 we present the observational data retrieved from the Multi-mission Archive at STScI (MAST); in Section 3 we discuss the main characteristics of the UV spectra of the WELS, and present line identifications of the most conspicuous features, as well as equivalent width and line flux measurements. In Section 4 we empirically measure the terminal velocities for all objects presenting P-Cygni profiles in N V $\lambda 1238$ and/or C IV $\lambda 1549$, from low and high resolution data. Finally, in Section 5, we discuss and compare the results obtained for the WELS to the data of A 30 and A 78 (the two prototype [WC]-PG 1159 stars), and present the main conclusions of our work.

2. OBSERVATIONAL DATA

We used public data from the *IUE* (*International Ultraviolet Explorer*) satellite, which are available at the Multi-mission Archive at STScI (MAST)¹. The total number of WELS currently known is about 50. Most of them are listed in the work of Tylanda et al. (1993) and Parthasarathy et al. (1998), and 15 were recently discovered in the direction of the Galactic bulge by Górny et al. (2004). Two objects considered as WELS in Parthasarathy et al. (1998) (Hen 2-86 and M 2-31) were found to be actually early type [WR] stars by Marcolino & de Araújo (2003) on the basis of the equivalent width of the C IV $\lambda 5805$ line.

We have searched for *IUE* data for all WELS known, and found spectra for only $\sim 40\%$ of the total WELS population. The list of SWP, LWP and LWR archives considered in our study, including the ones for A30 and A78 (the two [WC]-PG 1159 stars), is shown in Table 1. The majority of the spectra disponible are of low resolution ($\sim 6\text{\AA}$). The high resolution spectra ($\sim 0.2\text{\AA}$) which were utilized are also shown in the table. Most of the observations were done using the *IUE* large aperture mode ($10'' \times 20''$).

¹<http://archive.stsci.edu/>

3. THE ULTRAVIOLET SPECTRUM OF WELS

The “weak emission line” class of central stars is defined based on the optical spectrum. Tytenda et al. (1993) showed that the WELS are characterized mainly by a feature in $\lambda 4650$ (possibly a sum of N III, C III and C IV), and the C III $\lambda 5696$ and C IV $\lambda 5805$ transitions. Because their C IV $\lambda 5805$ line is usually weak, a [WCL] spectral classification seems reasonable for these stars at a first glance. However, the C III $\lambda 5696$ line is generally strong in the [WCL] class and it is weak or absent in the WELS. Conversely, because the C III $\lambda 5696$ is weak or absent, a [WCE] classification seems plausible. However, the C IV $\lambda 5805$ in [WCE] stars is much stronger than in the WELS. Besides these characteristics, the WELS are also known to present some absorptions in the optical from lines such as He II $\lambda 4541$ and $\lambda 5412$ (Parthasarathy et al. 1998; Marcolino & de Araújo 2003), indicating a stellar wind not so dense as it is the case of the [WR] stars, where the photospheric part is completely hidden.

Although we can say that the main characteristics of the WELS are known in the optical, their ultraviolet spectra were never discussed before. As we have mentioned, although some works in the UV involved some WELS, no attention was given to their evolutionary status or relation to the [WC]-PG 1159 stars. The present paper addresses directly this issue. Instead of presenting a homogeneous set of features, we found that the WELS can be divided in three main groups regarding their ultraviolet spectra:

1. presence of a strong P-Cygni in C IV $\lambda 1549$;
2. weak C IV $\lambda 1549$ in P-Cygni;
3. absence of P-Cygni features.

In Fig. 1 we show stars that are representatives of the first group. The total number of objects is 11: NGC 6629, NGC 6891, Hen 2-12, PB 8, Hen 2-108, NGC 6543, NGC 6567, NGC 6572, Vy 2-1, Hb7, and IC 4776. As can be seen, the C IV $\lambda 1549$ transition is often accompanied by N V $\lambda 1238$, also in P-Cygni. Some other lines present are He II $\lambda 1640$ (e.g. PB 8), Si IV $\lambda\lambda 1394, 1403$ (e.g. Hen 2-108), and C III $\lambda 1909$ (e.g. NGC 6891). A feature near $\sim 1720\text{\AA}$ is also exhibited by several objects, and it might be due to N IV or Si IV. Line identifications, measurements of equivalent widths and fluxes for all objects will be presented in the next section.

Only two stars were assigned to the second group, namely, CN 3-1 and Hen 2-131. Their spectra are shown in Fig. 2 (top and 2nd panel). The C IV $\lambda 1549$ line is clearly weaker than in group 1. As will be described later in Section 4, these two stars present also

significantly lower terminal velocities. Despite weak, the transitions Si IV $\lambda\lambda 1394, 1403$ can also be identified. The remaining objects are: J900, IC 4997, NGC 5873, NGC 6818, NGC 6803, and M 1-71. They compose the third group, and some of them are also shown in Fig. 2 (3rd to bottom panel). It can be readily noted the presence of strong emissions and of a weak and flat continuum. No P-Cygni emissions are seen. These characteristics suggest that only nebular features were detected by the *IUE* observations. Other archives than the ones listed in Table 1 were examined, but they all present similar spectra. An exception is the case of IC 4997. By analyzing another *IUE* archival spectrum (SWP08578) besides the one shown in Fig. 2 (SWP31683), we could see a slightly higher continuum and a N V $\lambda 1238$ line possibly in P-Cygni. We chose to keep this star in group 3 since the C IV $\lambda 1549$ line is not in P-Cygni in any other spectrum, including the ones in the high resolution mode (e.g. SWP41947). We have also included the star M 1-71 in group 3, although it shows only a featureless UV spectrum. For this object however, there is only one *IUE* file available, and it is possible that the central star was not within the *IUE* aperture during the observation.

One object does not fit in our division scheme, namely, IC 5217. The C IV $\lambda 1549$ line in this star is intense, but not in P-Cygni. On the other side, a P-Cygni is found in N V $\lambda 1238$, and also in O V $\lambda 1371$, although somewhat weak. Furthermore, this star does not present a flat continuum. We conclude that the wind spectrum is clearly visible in this star, but it is highly contaminated by nebular emissions.

We should emphasize that the three groups above were introduced by analyzing the $\sim 1150 - 2000\text{\AA}$ interval, and that although we have shown in Figs. 1 and 2 low resolution spectra, the characteristics of these groups are confirmed from the available high dispersion data. We chose the $\sim 1150 - 2000\text{\AA}$ region for two reasons. First, it is in this wavelength range that we have found practically all the P-Cygni lines. Obviously, such profiles are formed in the stellar wind of the central star - which is our main interest - and not in the nebula. Second, the $\sim 2000 - 3000\text{\AA}$ interval sometimes have no or very few features (see next section), whose nature (nebular or stellar) we cannot decide from low resolution data. The exception is the third group, where we have found various transitions, but as we previously argued, they are most likely nebular.

In addition to Figs. 1 and 2, we show in Fig. 3 the *IUE* spectra of the two prototype [WC]-1159 stars: A30 and A78, also at the same resolution. It is clear that these two objects have a spectrum that is remarkably different from the WELS spectra. The three P-Cygni lines N V $\lambda 1238$, O V $\lambda 1371$, and C IV $\lambda 1549$ are simultaneously present and more intense than in the WELS. Furthermore, the absorption part of these P-Cygni profiles (mainly in C IV $\lambda 1549$) are considerably broader, suggesting large terminal wind velocities (see Section 4). Although the E(B-V) for these stars have a role in determining the slope of

the continuum, it is also evident that the flux is higher in the blue ($\sim 1150\text{\AA}$) than in the red part of the *IUE* spectrum ($\sim 2000\text{\AA}$). This is not seen in most of the WELS, and might indicate that [WC]-PG 1159 stars have higher effective temperatures.

We have assigned the stars NGC 6567, NGC 6572, and NGC 6543, to the group presenting intense C IV $\lambda 1549$ in P-Cygni. However, in addition to the C IV $\lambda 1549$ line exhibited by the stars in group 1, these three objects also show simultaneously N V $\lambda 1238$ and O V $\lambda 1371$ P-Cygni emissions. This characteristic resembles the [WC]-PG 1159 class and is shown in Fig. 4. Thus, although a comparison between spectra shown in Fig. 1, 2, and 3 argue against those WELS being [WC]-PG 1159 stars, we cannot be sure regarding the objects shown in Fig. 4. In fact, the central star of NGC 6567 for example, was already considered as a [WC]-PG 1159 object by Hamann (1996). This point will be addressed later in the paper.

3.1. Line Identifications and Measurements

In Tables 2, 3, 4 and 5 we present line identifications, measurements of equivalent widths and line fluxes of all *IUE* low resolution spectra considered in this work. For completeness, we have included IC 5217 in Table 4, although this object does not belong to the group of WELS without P-Cygni emissions (group 3). The equivalent widths were measured by the conventional method of adjusting a Gaussian function to the line profile. When this was not possible, we have computed the line area above the adopted continuum. In the case of a P-Cygni profile, only its emission feature was considered in the measurement. We emphasize that our intention is not to construct an UV atlas for the WELS. Therefore, we have only listed and measured the most conspicuous lines in their spectra. It should also be kept in mind that throughout this paper we make reference to lines such as C IV $\lambda 1549$ and N V $\lambda 1238$, but the exact atomic transitions might be slightly different. In these two cases for example, the carbon and nitrogen lines are actually the doublets: C IV $\lambda\lambda 1548, 51$ and N V $\lambda\lambda 1238, 42$.

Previous studies have investigated the UV spectrum of some stars seen in Tables 2-5. In general, we have found a good agreement between our results and the ones that also present line measurements. For Vy 2-1, NGC 6629, M 1-71, and Hen 2-108, we found no reference in the literature regarding their *IUE* spectra from the MAST database. Although we can find references for the stars CN 3-1, NGC 6891, J900, Hen 2-12, NGC 5873, and NGC 6803, they generally involve a large sample of objects and are not focused on line identifications, measurements or the WELS evolutionary state. Details concerning some individual objects are discussed below.

NGC 6567: Although there are four references regarding this object in the MAST database, only the one of Hyung et al. (1993) have focused in some detail the main features of its ultraviolet spectrum. For C IV $\lambda 1549$, these authors found a line flux (in units of 10^{-13} ergs s $^{-1}$ cm $^{-2}$) of 12.8, while we have measured 13 ± 1 . Taking into consideration the uncertainty in the line measurements of their work (of $\sim 15\%$), our results present a very reasonable agreement for this line and others such as N V $\lambda 1238$, O V $\lambda 1371$, C II $\lambda 2325$, and Mg II $\lambda 2798$.

NGC 6572: There are several references to the UV spectrum of this object. The most important to our discussion is the one of Hyung et al. (1994), which presents a detailed high resolution spectral study from the UV to the optical, with several line identifications and measurements. Their main aim was however to explore diagnostic lines in the rich spectrum of NGC 6572 in order to determine plasma parameters, and not to discuss its evolutionary status.

NGC 6543: The *IUE* spectrum of this star was studied before by Bianchi et al. (1986) and Perinotto et al. (1989). Both works have heavily focused only in the determination of stellar and wind parameters (e.g. T_{eff} and \dot{M}). No comparison to other objects as in the context of the present paper was made.

PB 8: This planetary nebula was studied together with other 7 objects by Feibelman (2000). Line fluxes provided in his work are in good agreement with our measurements. For N V $\lambda 1238$ for example, we encountered ~ 2.6 (units of 10^{-13} ergs cm $^{-2}$ s $^{-1}$) while Feibelman derived 2.4. Although the emission in $\sim 1724\text{\AA}$ was identified in his work as N IV $\lambda 1719$, it is possible that it arises actually from Si IV $\lambda 1722$. In fact, we have also identified two lines in 1394\AA and 1403\AA which are likely to stem from Si IV.

Hen 2-131: Its *IUE* spectra were briefly discussed by Adams & Seaton (1982). However, the attention was given to the determination of the C/O ratio in the nebula, and not to the central star.

IC 4776: This object was studied by Herald & Bianchi (2004) by means of expanding atmosphere models, and its physical parameters and chemical abundances were obtained. As far as we are concerned, their work constitute the first to analyze the stellar wind of a WELS with a state-of-art non LTE code (CMFGEN; Hillier & Miller 1998). The same main observed wind emissions were identified in their and our paper. The O V $\lambda 1371$ is predicted by their model, but it is very weak or absent in the *IUE* spectrum. Herald & Bianchi (2004) have also analyzed the star A78, and a [WC]-PG 1159 classification was confirmed. Surprisingly, the physical parameters obtained for A78 and IC 4776 are quite different. A78 is almost twice hotter ($T_{eff} \sim 113kK$) and present a larger terminal velocity (3200 km s $^{-1}$)

than IC 4776. These findings support the idea that these two stars do not belong to the same spectroscopy class, i.e., that WELS are not [WC]-PG 1159 stars (see Section 5).

Hb7: Gauba et al. (2001) also analyzed the low *IUE* resolution spectrum of this star, together with another planetary nebula (Sp 3). Some wind parameters (e.g. \dot{M}) as well as the effective temperature and core mass were estimated, but no atmosphere models were used. The spectral energy distribution from the far infrared to the ultraviolet was also investigated. No line identifications and measurements were presented and the status of Hb7 as a WELS was not discussed.

NGC 6818: The spectrum of this object (nebular plus central star) was extensively studied by Hyung et al. (1999). We refer the reader to their work for a more detailed analyses than the one presented here. The chemical composition of the planetary nebula was further explored by the work of Pottasch et al. (2005).

IC 5217: A very similar analysis to NGC 6818 (Hyung et al. 1999) was done in the case of IC 5217 by Hyung et al. (2001). Again, we refer the reader to their work for detailed line identifications and measurements. We highlight that in both references the identity of these two stars as WELS is not discussed, and emphasis is given mainly to the determination of plasma parameters such as the electronic temperature, density, ionic concentrations, and chemical abundances.

4. TERMINAL VELOCITIES

In this section, we derive terminal velocities (v_∞) for all WELS presenting P-Cygni profiles in N V $\lambda 1238$ and/or C IV $\lambda 1549$. The v_∞ , together with the mass-loss rate (\dot{M}), constitute the most important physical parameters describing the stellar winds of hot stars. Their empirical determination are often used to test the theory of radiatively driven stellar winds, to compare stars of different spectral classes, and also as an input in stellar evolution models and interstellar medium studies (see for example Prinja et al. 1990; Lamers & Cassinelli 1999). The determination of \dot{M} for the WELS presenting wind features is beyond the scope of the present paper, since it requires sophisticated non LTE expanding atmosphere models for reliable estimates. Work is under way by our group to accomplish this goal.

Because only a few high resolution spectra are available, most of the terminal velocities of the WELS can only be obtained from low dispersion *IUE* spectra. A priori, an accurate determination of v_∞ from a $\sim 6\text{\AA}$ resolution spectrum is a complicated task, since we generally do not see an extended and saturated absorption in a P-Cygni line. Nevertheless, in order to overcome this difficulty, Prinja (1994) provided a relation between $\Delta\lambda$ (defined

below, obtained at low resolution) and v_∞ (obtained at high resolution) by analyzing a large sample of different hot stars (O, B, WR, and also CSPN). The resultant calibration of his work is represented by:

$$v_\infty = a_1 + a_2[\Delta\lambda] + a_3[\Delta\lambda]^2.$$

In this equation, $\Delta\lambda$ ($= \lambda_{peak} - \lambda_{min}$) is the wavelength difference between the peak and the absorption minima of a low resolution P-Cygni profile, and a_1 , a_2 and a_3 have different values for C IV $\lambda 1549$ and N V $\lambda 1238$ (see Prinja 1994). This calibration is perfectly suitable for our purpose, and obeys the definition of the terminal velocity from the black absorption core (v_{black}) of a P-Cygni line (Prinja et al. 1990).

In Table 6 we present the terminal velocities derived for the WELS, and also for the [WC]-PG 1159 stars A30 and A78. We used the usual method for WELS with high resolution spectra (using the Doppler effect and v_{black}) and the equation described above for low resolution spectra. We estimate the errors in the determination of v_∞ to be $\sim 20\%$.

The most important thing to be noted in Table 6 is that A30 and A78 have much higher terminal velocities than the WELS. While the majority of WELS have values concentrated in the $\sim 1000 - 1500 \text{ km s}^{-1}$ interval, these two [WC]-PG 1159 stars have a terminal velocity of $\sim 3000 \text{ km s}^{-1}$ (from C IV). Such high differences cannot be explained by the uncertainties in the measurements. Although different works in the literature have estimated v_∞ for A30 and A78, we have also measured this quantity in their low resolution spectra to follow the same method applied for the other stars (Prinja’s calibration). Among the previous studies regarding A30, we highlight the work of Harrington & Feibelman (1984), who obtained a terminal velocity of $\sim 4000 \text{ km s}^{-1}$. At that time however, the v_∞ determination was based on the largest negative velocity seen in a P-Cygni profile (when the line returns to the continuum). This procedure tends to obtain larger values than the v_{black} method (Prinja et al. 1990). The central star of A78 was recently analyzed by sophisticated non LTE atmosphere models by Herald & Bianchi (2004). These authors found that a velocity of $\sim 3200 \text{ km s}^{-1}$ could satisfactorily represent v_∞ , a value slightly higher than ours.

Other informations can be obtained by analyzing Table 6. It is clear for example, that CN 3-1 and Hen 2-131 have lower terminal velocities than most of the WELS. Indeed, as we have shown in Section 3 (Fig. 2), their UV spectra are quite different.

In order to further illustrate the differences between the terminal velocities of the WELS and the two prototype [WC]-PG 1159 stars A30 and A78, as shown in Table 6, and to compare the results obtained to other hydrogen deficient CSPN, we present in Fig. 5 the v_∞ distribution for several stars belonging to the spectroscopic classes [WCL], [WCE], [WC]-PG

1159, WELS, and PG 1159. Once again, it can be seen that the terminal velocities measured for the WELS are mainly concentrated between $\sim 1000 - 1500 \text{ km s}^{-1}$. Moreover, their v_∞ tends to be higher and lower than in the [WCL] and [WCE] class, respectively. It is also clear that the [WC]-PG 1159 class (represented by the two prototype stars A30 and A78) and the few PG 1159 stars that show a stellar wind, have the highest terminal velocities among the hydrogen deficient CSPN.

5. DISCUSSION AND CONCLUSIONS

From a comparison between several optical spectra of WELS, [WC]-PG 1159, and PG 1159 stars, Parthasarathy et al. (1998) have proposed that the WELS are actually [WC]-PG 1159 stars. This claim was not confirmed by further studies and as we mentioned, some authors have warned about this assertion until a more comprehensive study is achieved (Werner & Herwig 2006). After an analysis of the main UV characteristics of the WELS and the two prototype [WC]-PG 1159 stars A30 and A78, our next step was to compare the results obtained for these two class of objects in order to address this important issue.

As we have shown, most of the WELS present a UV spectrum considerably different from the [WC]-PG 1159 stars. While this last class present simultaneously P-Cygni profiles in N V $\lambda 1238$, O V $\lambda 1371$, and C IV $\lambda 1549$, the majority of WELS present a very weak or no O V $\lambda 1371$ (see Fig. 1). The same is true at least for some objects regarding the N V $\lambda 1238$ line. The only exceptions are the objects NGC 6543, NGC 6567, and NGC 6572. Their spectra in fact resemble the ones of the [WC]-PG 1159 stars (see Figs. 3 and 4): their O V $\lambda 1371$ line is clearly visible as well as the other transitions mentioned.

Besides the spectral differences found in the ultraviolet part of the spectrum, we have also found that the terminal velocities of the WELS are considerably lower than in [WC]-PG 1159 stars. Our Table 6 shows that the bulk of the WELS have v_∞ between $\sim 1000 - 1500 \text{ km s}^{-1}$, and A30 and A78 have values about 3000 km s^{-1} . This difference might represent different physical parameters underlying these two class of stars. The theory of radiatively driven stellar winds for example, predicts that the terminal velocity of a star is related with the escape velocity (v_{esc}), which in turn depend on other physical parameters (e.g. mass and radius; Abbott 1978; Lamers & Cassinelli 1999). Moreover, v_∞ is also known to correlate with the effective temperature (T_{eff}) in several class of stars (see Fig. 8 of Prinja et al. 1990). The T_{eff} tends to be higher for stars with high terminal velocities.

From the considerations above described, we conclude that the [WC]-PG 1159 stars are distinct from the WELS, in contrast with the claim made by Parthasarathy et al. (1998)

on the basis of optical spectroscopy. It should be noted however, that the situation for the central stars NGC 6543, NGC 6567 and NGC 6572 is ambiguous. From one side, they have a spectrum compatible with the [WC]-PG 1159 class. On the other hand, they do not present high terminal velocities as it is the case of A30 and A78. From both low and high resolution data it is obtained v_{∞} values less than 2000 km s^{-1} for these three stars (see Table 6).

If the WELS are not [WC]-PG 1159 stars, what is their role in the evolutionary sequence [WR] \rightarrow PG 1159 ? Do they form an alternative channel of evolution ? In order to elucidate these and other similar questions, and to further clarify the differences between them and the [WC]-PG 1159 stars, we clearly need to determine their physical parameters and chemical abundances. Non LTE expanding atmosphere models are being computed with this purpose by our group with the CMFGEN code of Hillier & Miller (1998). In this way, their position in the HR diagram could be determined, a more efficient comparison to [WR], [WC]-PG 1159 and PG 1159 stars could be made, and their evolutionary status could be better determined.

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REFERENCES

- Abbott, D. C., 1978, *ApJ*, 225, 893
- Acker, A., & Neiner, C., 2003, *A&A*, 403, 659
- Adams, S., & Seaton, M. J., 1982, *MNRAS*, 200, 7
- Bianchi, L., Cerrato, S., & Grewing, M., 1986, *A&A*, 169, 227
- Crowther, P. A., De Marco, O., & Barlow, M. J., 1998, *MNRAS*, 296, 367
- De Marco, O., & Soker, N., 2002, *PASP*, 114, 602
- Feibelman, W. A., 2000, *PASP*, 112, 861
- Gauba, G., Parthasarathy, M., Nakada, Y., & Fuji, T., 2001, *A&A*, 373, 572
- Gesicki, K., Zijlstra, A. A., Acker, A., Górny, S. K., Goździewski, K., & Walsh, J. R., 2006, *A&A*, 451, 925
- Górny, S. K., Stasińska, G., Escudero, A. V., & Costa, R. D. D., 2004, *A&A*, 427, 231

- Hamann, W. -R., 1996, *Ap&SS*, 238, 31
- Hamann, W. -R., 1997, in *Proc. IAU Symp. 180, Planetary Nebulae*, ed. H. J. Habing & H. J. G. L. M. Lamers (Dordrecht:Kluwer), 91
- Harrington, J. P., & Feibelman, W. A., 1984, *ApJ*, 277, 716
- Herald, J. E., & Bianchi, L., 2004, *ApJ*, 609, 378
- Herwig, F., 2001, *Ap&SS*, 275, 15
- Hillier, D. J., & Miller, D. L., 1998, *ApJ*, 496, 407
- Hyung, S., Aller, L. H., & Feibelman, W. A., 1993, *PASP*, 105, 693
- Hyung, S., Aller, L. H., & Feibelman, W. A., 1994, *MNRAS*, 269, 975
- Hyung, S., Aller, L. H., & Feibelman, W. A., 1999, *ApJ*, 514, 878
- Hyung, S., Aller, L. H., Feibelman, W. A., & Lee, W-B., 2001, *AJ*, 122, 954
- Koesterke, L., Dreizler, S., & Rauch, T., 1998, *A&A*, 330, 1041
- Koesterke, L., & Werner, K., 1998, *ApJL*, 500, 55
- Koesterke, L., 2001, *Ap&SS*, 275, 41
- Lamers, Henny J. G. L. M., Cassinelli, J. P., 1999, *Introduction to Stellar Winds*, Cambridge University Press
- Marcolino, W. L. F., & de Araújo, F. X., 2003, *AJ*, 126, 887
- Marcolino, W. L. F., Hillier, D. J., de Araújo, F. X., & Pereira, C. B., 2007, *ApJ*, 654, 1068
- Parthasarathy, M., Acker, A., & Stenholm, B., 1998, *A&A*, 329, L9
- Penã, M., Stasińska, G., & Medina, S., 2001, *A&A*, 367, 983
- Penã, M., Medina, S., & Stasińska, G., 2003, *RevMexAA*, 18, 84
- Perinotto, M., Cerruti-Sola, M., & Lamers, H. J. G. L. M., 1989, *ApJ*, 337, 382
- Pottasch, S. R., Beintema, D. A., & Feibelman, W. A., 2005, *A&A*, 436, 953
- Prinja, R. K., Barlow, M. J., & Howarth, I. A., 1990, *ApJ*, 361, 607
- Prinja, R. K., 1994, *A&A*, 289, 221

Tylenda, R., Acker, A., & Stenholm, B., 1993, A&AS, 102, 595

Werner, K., Dreizler, S., Heber, U., Kappelman, N., Kruk, J., Rauch, T., & Wolff, B., 1997, RvMA, 10, 219

Werner, K., & Herwig, F., 2006, PASP, 118, 183

Zijlstra, A. A., van Hoof, P. A. M., Chapman, J. M., & Loup, C., 1994, A&A, 290, 228

Table 1. Observational Data Utilized.

PN G	Star	Data Set	Resolution	Aperture
002.0-13.4	IC 4776	SWP16504,LWP13842	Low	Large
003.9-14.9	HB 7	SWP52257	Low	Large
007.0-06.8	Vy2-1	SWP44200	Low	Large
009.4-05.0	NGC 6629	SWP35968,LWP15329	Low	Large
011.7-00.6	NGC 6567	SWP45362,LWP23708	Low	Large
025.8-17.9	NGC 6818	SWP01704,LWR10557	Low	Large
034.6+11.8	NGC 6572	SWP42043,LWP20787,SWP42059	Low/High	Large
038.2+12.0	CN 3-1	SWP31600,LWP11819	Low	Large
046.4-04.1	NGC 6803	SWP06256,LWR05428	Low	Large
054.1-12.1	NGC 6891	SWP08173,LWP23363,SWP33503	Low/High	Large
055.5-00.5	M 1-71	SWP31678	Low	Large
058.3-10.9	IC 4997	SWP31683,LWP20706	Low	Large
096.4+29.9	NGC 6543	SWP54891,LWP24732,SWP03323	Low/High	Large
100.6-05.4	IC 5217	SWP07257,LWR01785	Low	Large
194.2+02.5	J 900	SWP53870,LWP29940	Low	Large
253.9+05.7	HEN 2-12	SWP16346,LWR12565	Low	Large
292.4+04.1	PB 8	SWP30476	Low	Large
315.1-13.0	HEN 2-131	SWP47003,LWR05736,SWP07653	Low/High	Large
316.1+08.4	HEN 2-108	SWP47513,LWP25380	Low	Large
331.3+16.8	NGC 5873	SWP30150	Low	Large
208.5+33.2	A30	SWP07955	Low	Small
081.2-14.9	A78	SWP44942,SWP19906	Low/High	Large

Table 2. WELS with strong C IV $\lambda 1549$ in P-Cygni.

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
Vy 2-1	1246.3*	N V $\lambda 1238$	-13 ± 3	0.62 ± 0.08
	1552.9*	C IV $\lambda 1549$	-6.4 ± 1.6	0.56 ± 0.08
	1721.0	N IV $\lambda 1719?$, Si IV $\lambda 1722?$	-4.7 ± 1.1	0.42 ± 0.07
	1906.7	C III $\lambda 1909$	-6.8 ± 1.2	0.5 ± 0.07
NGC 6543	1243.6*	N V $\lambda 1238$	-6.0 ± 0.8	540 ± 40
	1376.4*	O V $\lambda 1371$	-3 ± 1	300 ± 100
	1551.6*	C IV $\lambda 1549$	-8 ± 1	510 ± 50
	1639.8	He II $\lambda 1640$	-3.7 ± 0.4	200 ± 20
	1720.0*	N IV $\lambda 1719?$, Si IV $\lambda 1722?$	-2.5 ± 0.3	110 ± 10
	1907.8	C III $\lambda 1909$	-4.9 ± 0.8	170 ± 20
NGC 6567	1246.5*	N V $\lambda 1238$	-6 ± 1	7 ± 1
	1336.1	C II $\lambda 1334 - 36$	-4.3 ± 0.9	5.8 ± 0.9
	1377.2*	O V $\lambda 1371$	-3.6 ± 0.3	4.5 ± 0.3
	1553.4*	C IV $\lambda 1549$	-11 ± 1	13 ± 1
	1667.1	O III $\lambda 1666 - 69$	-1.2 ± 0.5	1.2 ± 0.4
	1908.7	C III $\lambda 1909$	saturated	saturated
	2326.7	C II $\lambda 2325$	-27 ± 4	6.3 ± 0.4
	2798.4	Mg II $\lambda 2796 - 98$	-15 ± 1	6.6 ± 0.4
NGC 6572	1244.6*	N V $\lambda 1238$	-7.1 ± 0.9	47 ± 4
	1375.4*	O V $\lambda 1371$	-1.8 ± 0.4	16 ± 3
	1551.5*	C IV $\lambda 1549$	-6.4 ± 0.7	51 ± 4
	1641.3	He II $\lambda 1640$	-4.5 ± 0.6	33 ± 3
	1664.6	O III $\lambda 1666 - 69$	-4.2 ± 0.4	29 ± 2
	1721.5	N IV $\lambda 1719?$, Si IV $\lambda 1722?$	-1.7 ± 0.4	10 ± 2
	1750.7	N III $\lambda 1751$	-4.7 ± 0.4	29 ± 2
	1815.3	Ne III $\lambda 1815$	-0.8 ± 0.1	4.4 ± 0.5
	1907.9	C III $\lambda 1909$	saturated	saturated
	2169.0	C III $\lambda 2163?$	-12 ± 8	21 ± 7
	2293.6	C III $\lambda 2293 - 97$	-3 ± 1	7 ± 2
	2326.9	C II $\lambda 2325$	-46 ± 5	117 ± 10

Table 2—Continued

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
	2470.3	O II λ 2470	-18 ± 1	59 ± 2
NGC 6891	1245.3*	N V λ 1238	-5.8 ± 0.7	45 ± 3
	1434.0	C I λ 1432?	-1.4 ± 0.7	13 ± 5
	1552.9*	C IV λ 1549	-5.1 ± 0.8	47 ± 5
	1723.0	N IV λ 1719?, Si IV λ 1722?	-1.3 ± 0.2	9 ± 1
	1908.0	C III λ 1909	-6.8 ± 0.5	44 ± 2
NGC 6629	1247.8*	N V λ 1238	-5.5 ± 2.4	2.3 ± 0.8
	1554.0*	C IV λ 1549	-4.4 ± 0.3	4.6 ± 0.2
	1724.3*	N IV λ 1719?, Si IV λ 1722?	-0.9 ± 0.2	0.8 ± 0.2
	1908.5	C III λ 1909	-4.3 ± 0.6	2.5 ± 0.3
Hen 2-12	1246.4*	N V λ 1238	-5.2 ± 0.8	17 ± 2
	1554.2*	C IV λ 1549	-5.5 ± 0.4	20 ± 1
	1723.4*	N IV λ 1719?, Si IV λ 1722?	-0.7 ± 0.2	2.1 ± 0.7
Pb 8	1245.9*	N V λ 1238	-3.6 ± 0.5	2.6 ± 0.3
	1382.2*	O V λ 1371?	-2.2 ± 0.4	1.8 ± 0.3
	1397.1*	Si IV λ 1394?	-1.2 ± 0.1	1.0 ± 0.1
	1413.1*	Si IV λ 1403?	-1.3 ± 0.3	1.1 ± 0.2
	1554.5*	C IV λ 1549	-7.5 ± 0.5	7.1 ± 0.3
	1643.4*	He II λ 1640	-2.1 ± 0.2	1.9 ± 0.1
	1724.1*	N IV λ 1719?, Si IV λ 1722?	-2.7 ± 0.5	2.2 ± 0.4
Hen 2-108	1245.1*	N V λ 1238	very weak or absent	very weak or absent
	1394.9*	Si IV λ 1394	-1.5 ± 0.5	1.8 ± 0.5
	1403.8*	Si IV λ 1403	-1.7 ± 0.4	2.2 ± 0.4
	1551.9*	C IV λ 1549	-2.9 ± 0.4	4.6 ± 0.5
IC 4776	1245.3*	N V λ 1238	-4 ± 2	11 ± 5
	1554.9*	C IV λ 1549	-2.8 ± 0.5	7 ± 1
	1751.6	N III λ 1751	-2.5 ± 0.6	5 ± 1

Table 2—Continued

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
	1909.3	C III λ 1909	-13 ± 1	23 ± 1
	2468.2	O II λ 2470	-14 ± 1	15 ± 1
Hb 7	1245.2*	N V λ 1238	saturated	saturated
	1554.3*	C IV λ 1549	-2.7 ± 0.4	10 ± 1
	1907.9	C III λ 1909	saturated	saturated

Note. — An asterisk denotes P-Cygni emission components. Ly α is present in several spectra and has geocoronal origin.

Table 3. WELS with weak C IV $\lambda 1549$ in P-Cygni.

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
Cn 3-1	1397.3*	Si IV $\lambda 1394$	-0.8 ± 0.1	1.7 ± 0.2
	1406.5*	Si IV $\lambda 1403$	-1.1 ± 0.1	2.4 ± 0.1
	1554.1*	C IV $\lambda 1549$	-1.1 ± 0.6	2 ± 1
	2470.2	O II $\lambda 2470$	-3 ± 1	4 ± 1
Hen 2-131	1394.7*	Si IV $\lambda 1394$	-0.8 ± 0.2	22 ± 4
	1403.4*	Si IV $\lambda 1403$	-1.0 ± 0.3	30 ± 7
	1551.6*	C IV $\lambda 1549$	-1.2 ± 0.5	28 ± 9

Note. — An asterisk denotes P-Cygni emission components. Ly α is present in several spectra and has geocoronal origin.

Table 4. WELS without C IV $\lambda 1549$ in P-Cygni.

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
IC 4997	1305.8	O I $\lambda 1305$	-19 ± 7	7 ± 1
	1483.9	N IV $\lambda 1483, 86$	-10 ± 7	4 ± 1
	1549.8	C IV $\lambda 1549$	-71 ± 13	42 ± 1
	1642.0	He II $\lambda 1640$	-11 ± 4	7 ± 1
	1665.0	O III $\lambda 1666$	-92 ± 18	62 ± 2
	1750.9	N III $\lambda 1750$	-46 ± 9	30 ± 2
	1909.1	C III $\lambda 1909$	saturated	saturated
	2324.1	O III $\lambda 2321?$, C II $\lambda 2325?$	-78 ± 35	22 ± 3
	2473.9	O II $\lambda 2470$	-25 ± 14	14 ± 5
	2799.7	Mg II $\lambda 2796 - 98$	-14 ± 6	13 ± 4
	3187.8	He I $\lambda 3188$	-27 ± 6	20 ± 2
J900	1547.2	C IV $\lambda 1549$	-567 ± 136	50 ± 1
	1638.5	He II $\lambda 1640$	-284 ± 75	19 ± 1
	1664.0	O III $\lambda 1666$	-62 ± 14	3.2 ± 0.3
	1906.7	C III $\lambda 1909$	saturated	saturated
	2299.8	C III $\lambda 2298$	-75 ± 50	1.4 ± 0.3
	2329.3	O III $\lambda 2321?$, C II $\lambda 2325?$	-402 ± 129	8.2 ± 0.1
	2425.7	Ne IV $\lambda 2422, 24$	-86 ± 13	4.8 ± 0.1
	2473.9	O II $\lambda 2470$	-8 ± 2	0.5 ± 0.1
	2515.7	He II $\lambda 2511$	-11 ± 3	0.8 ± 0.1
	2735.6	He II $\lambda 2733$	-13 ± 1	1.5 ± 0.1
	2802.5	Mg II $\lambda 2796 - 98$	-9 ± 3	1.1 ± 0.3
	2838.1	O III $\lambda 2836$	-10 ± 2	1.4 ± 0.1
	3026.4	O III $\lambda 3023 - 26$	-7 ± 1	1.2 ± 0.1
	3048.8	O III $\lambda 3046$	-14 ± 2	2.4 ± 0.2
	3134.7	O III $\lambda 3133$	-88 ± 9	14 ± 1
	3206.1	He II $\lambda 3203$	-39 ± 3	6.4 ± 0.2
NGC 5873	1478.7	N IV $\lambda 1483, 86$	-7 ± 2	1.8 ± 0.2
	1520.9	Si II $\lambda 1527$	-11 ± 2	2.7 ± 0.4
	1544.7	C IV $\lambda 1549$	-106 ± 19	27 ± 1
	1635.5	He II $\lambda 1640$	-149 ± 34	29 ± 1

Table 4—Continued

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
	1660.2	O III λ 1666	-18 ± 4	3.2 ± 0.4
	1903.7	C III λ 1909	-158 ± 15	30 ± 1
NGC 6818	1238.4	N V λ 1238	-14 ± 4	7 ± 1
	1401.4	O IV λ 1397 – 1405	-20 ± 3	18 ± 1
	1482.7	N IV λ 1483, 86	-24 ± 2	20 ± 1
	1547.3	C IV λ 1549	-103 ± 9	81 ± 1
	1600.8	Ne IV λ 1601	-11 ± 3	8 ± 1
	1638.8	He II λ 1640	-258 ± 26	230 ± 10
	1663.4	O III λ 1666	-20 ± 3	19 ± 2
	1749.0	N III λ 1750	-23 ± 3	17 ± 1
	1906.8	C III λ 1909	-450 ± 69	320 ± 10
	2327.0	C II λ 2323 – 28	-67 ± 10	14 ± 1
	2425.9	Ne IV λ 2422, 24	-188 ± 30	43 ± 1
	2512.8	He II λ 2511	-16 ± 3	4.1 ± 0.5
	2734.9	He II λ 2733	-28 ± 2	8.0 ± 0.3
	2835.2	O III λ 2836	-18 ± 3	6.1 ± 0.6
	3023.8	O III λ 3023 – 26	-9.0 ± 0.7	3.1 ± 0.2
	3046.9	O III λ 3043 – 3047	-28 ± 4	10 ± 1
	3132.2	O III λ 3133	-145 ± 17	58 ± 1
	3203.9	He II λ 3203	-37 ± 7	16 ± 1
NGC 6803	1641.3	He II λ 1640	-42 ± 11	1.6 ± 0.1
	1909.4	C III λ 1909	-20 ± 3	18 ± 1
IC 5217	1244.5*	N V λ 1238	-5.7 ± 0.5	2.7 ± 0.2
	1376.8*	O V λ 1371	-1.0 ± 0.4	0.7 ± 0.2
	1548.5	C IV λ 1549	-14 ± 1	9.2 ± 0.2
	1639.6	He II λ 1640	-15 ± 1	9.7 ± 0.3
	1663.2	O III λ 1666	-6.3 ± 0.6	3.7 ± 0.3
	1751.7	N III λ 1750	-2.4 ± 0.4	1.4 ± 0.2
	1906.9	C III λ 1909	-54 ± 4	21 ± 1
	2333.2	?	-29 ± 10	5.1 ± 0.9

Table 4—Continued

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
	3133.1	O III λ 3133	-26 ± 7	6.4 ± 0.9

Note. — An asterisk denotes P-Cygni emission components. Ly α is present in several spectra and has geocoronal origin.

Table 5. Line identifications and measurements for A30 and A78.

Star	λ_{obs}	Transition	W_λ	Flux (10^{-13} ergs s $^{-1}$ cm $^{-2}$)
A 30	1246.2*	N V λ 1238	-6.1 ± 0.8	16 ± 1
	1374.2*	O V λ 1371	-5.0 ± 0.6	13 ± 1
	1556.7*	C IV λ 1549	-9 ± 1	18 ± 2
A 78	1246.2*	N V λ 1238	-8 ± 1	140 ± 10
	1374.3*	O V λ 1371	-3.7 ± 0.5	54 ± 6
	1554.2*	C IV λ 1549	-7 ± 1	77 ± 8

Note. — An asterisk denotes P-Cygni emission components. Ly α is present in several spectra and has geocoronal origin.

Table 6. Terminal velocities of WELS and [WC]-PG 1159 stars.

Star	v_{∞} (km s ⁻¹)	
	C IV $\lambda 1549$	N V $\lambda 1238$
WELS		
Vy2-1	1060	-
NGC 6891	1420 (1396)	1200 (1339)
NGC 6629	1230	-
HEN 2-12	1100	1230
PB 8	1070	1220
HEN 2-108	720	-
IC 4776	1760	1770
HB 7	1077	1150
NGC 6567	1750	1680
NGC 6572	1070 (1280)	1200 (1206)
NGC 6543	1420 (1684)	1260 (1552)
CN 3-1*	329	-
HEN 2-131*	710 (520)	-
[WC]-PG 1159		
A 30	3080	2600
A 78	2870 (3080)	2594 (2780)

Note. — An asterisk indicates stars with weak C IV $\lambda 1549$ in P-Cygni (Group 2). Measurements in high resolution spectra are shown between parenthesis.

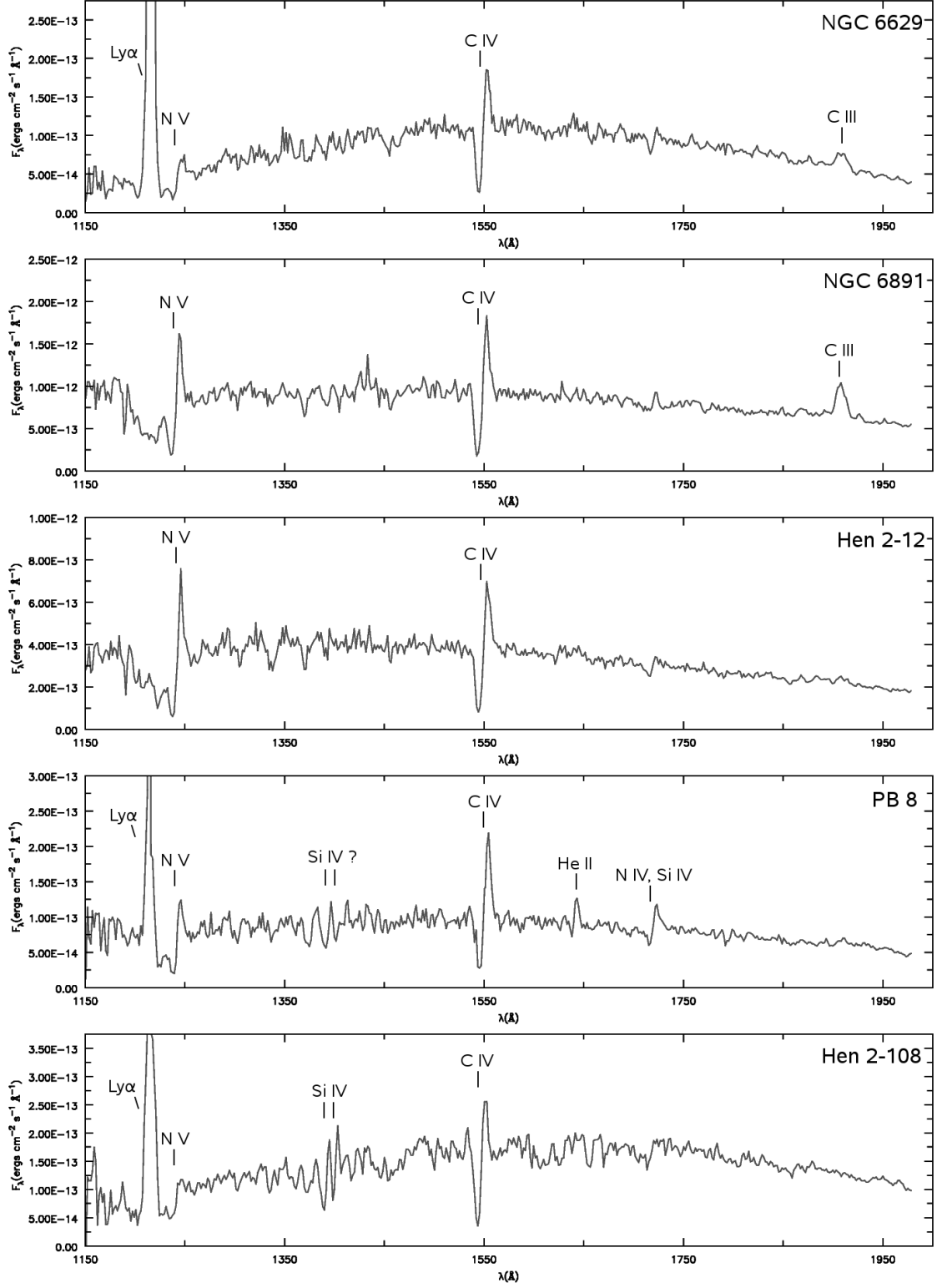


Fig. 1.— WELS presenting strong P-Cygni profiles (group 1) in C IV $\lambda 1549$. The N V $\lambda 1238$ is often present and also in P-Cygni. Low resolution *IUE* spectra ($\sim 6\text{\AA}$).

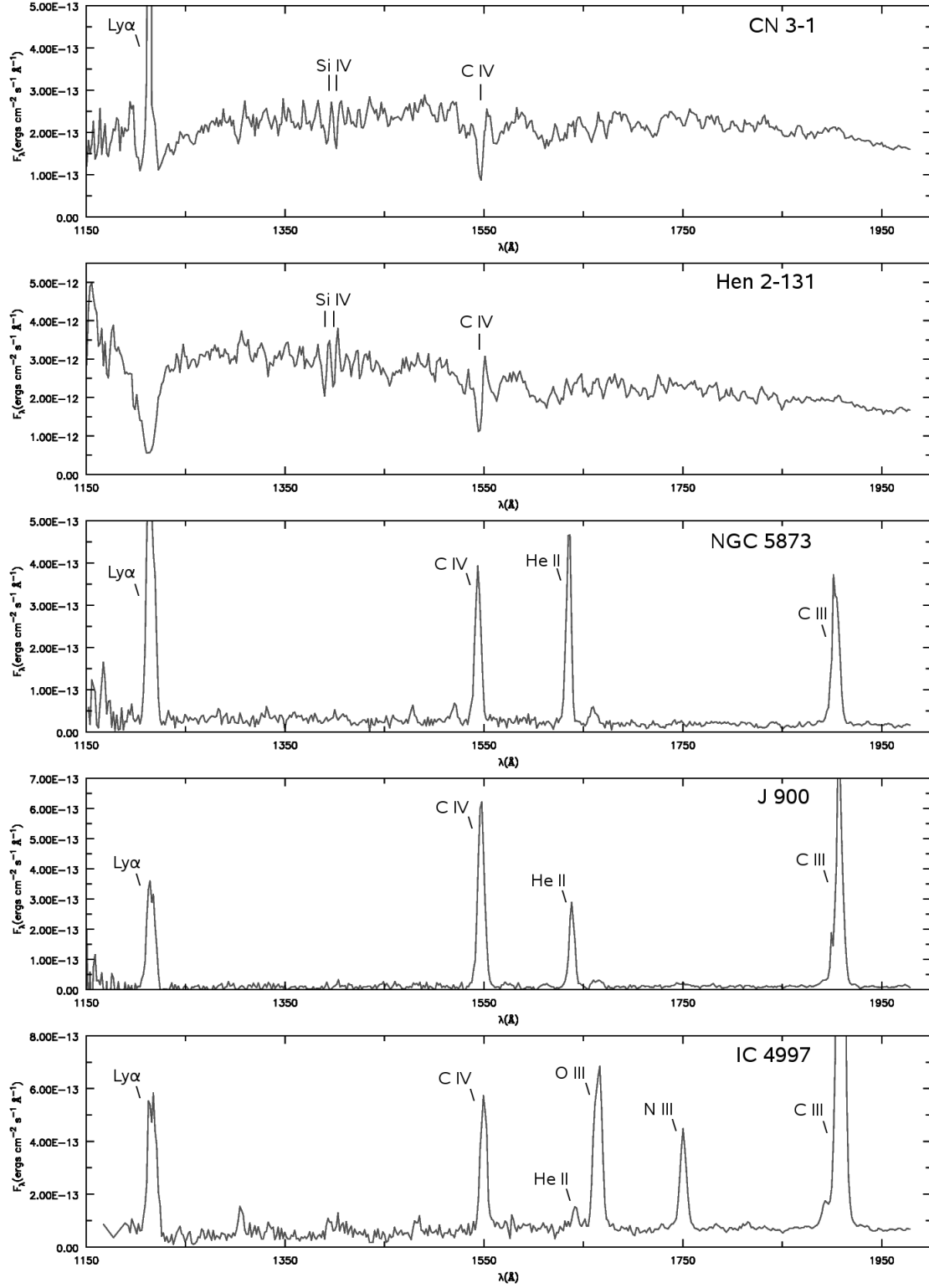


Fig. 2.— WELS presenting weak P-Cygni profiles in C IV $\lambda 1549$ (group 2): top and 2nd panels. WELS presenting absence of P-Cygnis and very weak continuum (group 3): 3rd to 5th panels. Low resolution *IUE* spectra ($\sim 6\text{\AA}$).

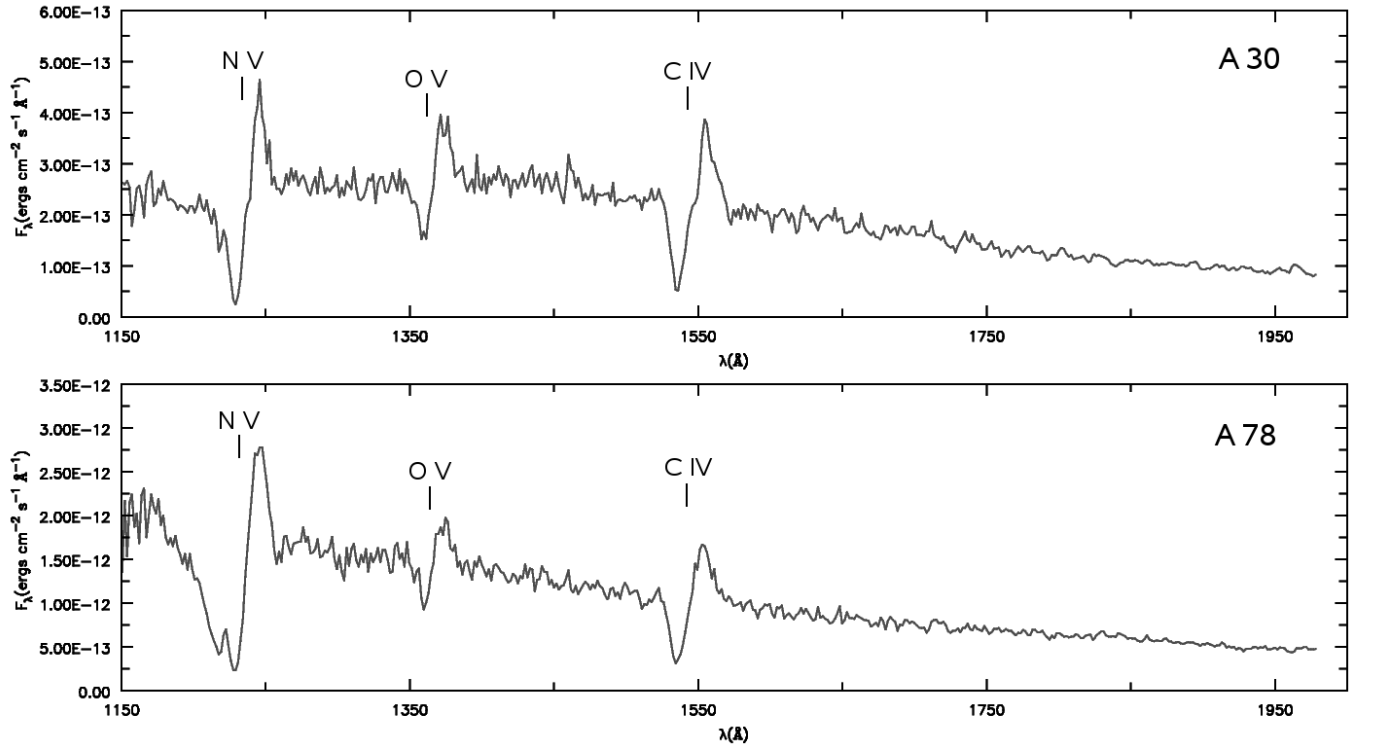


Fig. 3.— Low resolution *IUE* spectra of the two prototype [WC]-PG 1159 stars - A 30 (top) and A 78 (bottom).

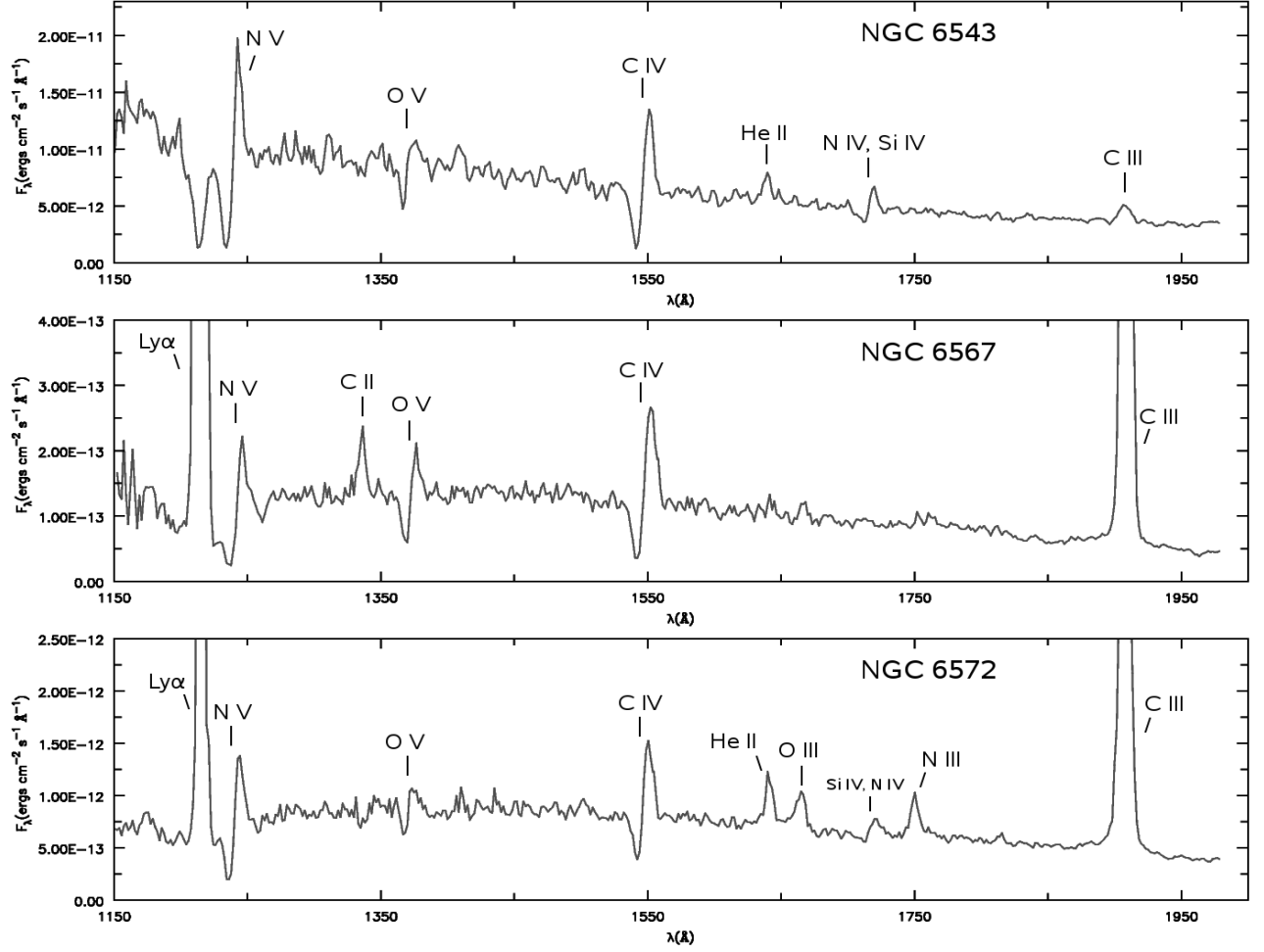


Fig. 4.— Low resolution *IUE* spectra of WELS resembling [WC]-PG 1159 stars: NGC 6543, NGC 6567, and NGC 6572.

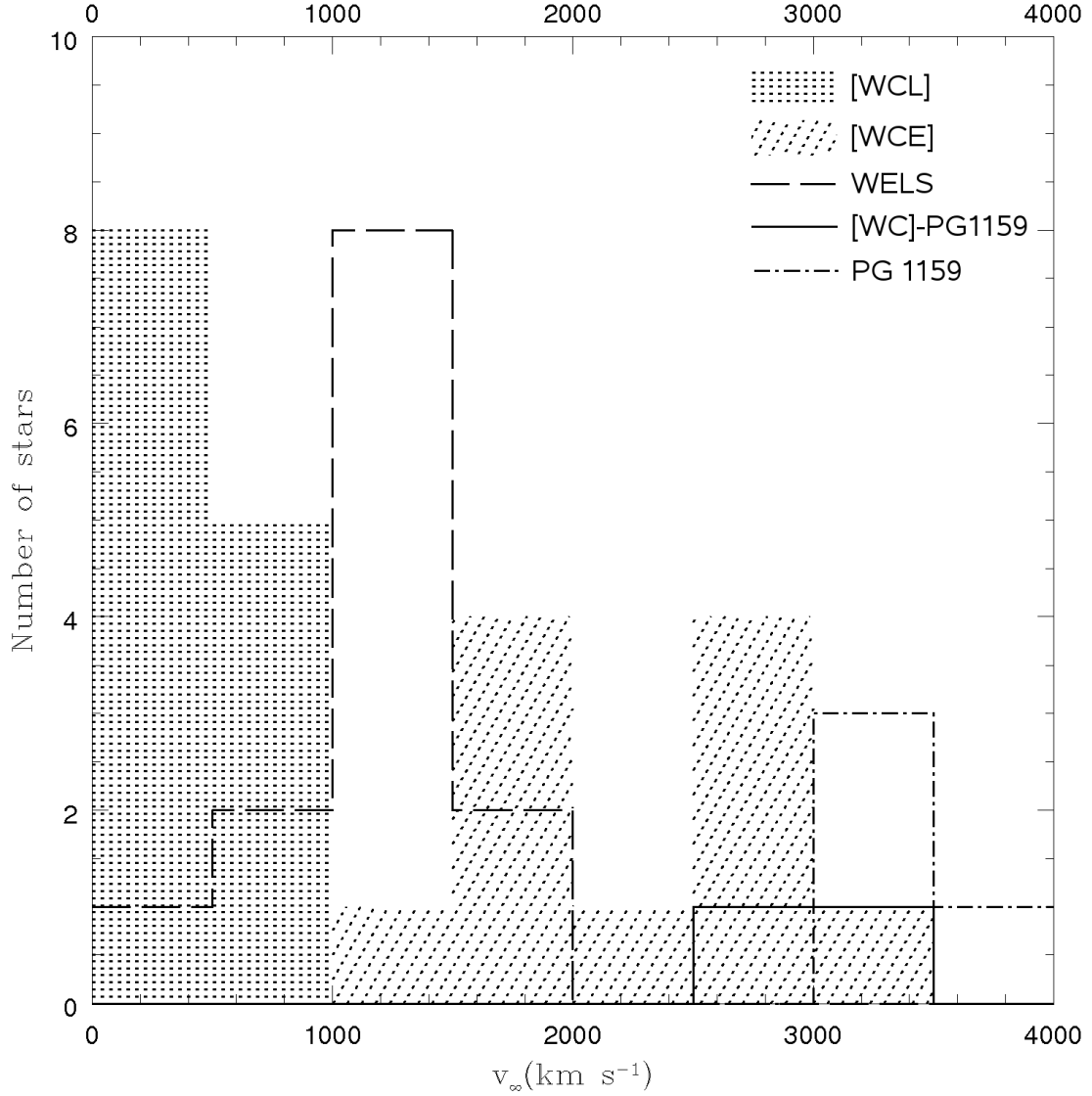


Fig. 5.— Distribution of terminal velocities of [WCL], [WCE], WELS, [WC]-PG 1159, and PG 1159 stars. The data for the WELS and [WC]-PG 1159 stars were homogeneously obtained from low resolution *IUE* spectra using C IV $\lambda 1549$ and the calibration of Prinja (1994). The terminal velocities for the [WCL], [WCE] and PG 1159 stars are from Koesterke (2001), and were obtained by means of non LTE expanding atmosphere models. The bin width is 500 km s⁻¹.